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ABSTRACT

During the time period of December 1970 to September 1971 an International Satellite Geodesy Experiment (ISAGEX) was conducted. Over fifty optical and laser tracking stations participated in the data gathering portion of this experiment. Data from some of the stations had not been previously available for dynamical orbit computations. With the recent availability of new data from the Astrosoviet, East European and other optical stations, orbital analyses were conducted at GSFC to insure compatibility with the previously available laser data. These data have also been analyzed using dynamical orbital techniques for the estimation of geocentric coordinates for six camera stations (four Astrosoviet, two East European). This preliminary solution is based upon a combination of data from these stations with National Aeronautics and Space Administration (NASA), Smithsonian Astrophysical Observatory (SAO), and Groupe de Recherches de Geodesie Spatiale (GRGS) laser data, and optical data from SAO and GRGS. Thirteen arcs of GEOS-I and II observations between two and four days in length were used. The uncertainty in these new station values is considered to be about 20 meters in each coordinate. Adjustments to the previously available values were generally a few hundred meters. With these geocentric coordinates these data will now be used to supplement our Earth Physics investigations during the ISAGEX.

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CONTENTS

ILLUSTRATIONS

TABLES

ANALYSES OF PRECISION REDUCED OPTICAL OBSERVATIONS FROM THE INTERNATIONAL SATELLITE GEODESY EXPERIMENT (ISAGEX)

1.0 INTRODUCTION

The ISAGEX experiment was initiated by the French Centre National d'Etudes Spatiales (CNES) in the autumn of 1969 through a proposal for an international laser and photographic compaign on satellites equipped with laser reflectors.

The ISAGEX experiment was endorsed by the COSPAR XIIIth General Assembly, Leningrad, 1970. The objective of the program was to collect a set of homogeneous and well distributed precise laser and camera satellite observations for the purposes of dynamic and geometric geodesy. The experiment involved seventeen countries and over fifty tracking stations. The data gathering portion of the experiment extended from December 1970 to September 1971. The laser data consisting of over 1900 passes were delivered to the data bank at CNES in January 1972. As of May 1973 over 7000 pairs of optical data had also been placed in the data bank.

The authors have previously reported the results of a dynamical solution which combined ISAGEX laser data with the optical and laser tracking data recorded during the National Geodetic Satellite Program (NGSP) and the CNES/SAO 1968 Observing Program for the simultaneous recovery of coordinates for over 70 tracking stations (Marsh, Douglas, Klosko, 1973). This present paper represents a continuation of the analyses of the ISAGEX data using the optical data presently available.

2.0 DESCRIPTION OF THE SOLUTION

Goddard Space Flight Center (GSFC) received in May 1973 from the ISAGEX data bank at CNES a magnetic tape containing all available precision reduced optical data. Table 1 presents a summary of these data from the following satellites; MIDAS-4, BE-B, BE-C, GEOS-1, PAGEOS, D1-C, D1-D, GEOS-II and PEOLE. Laser data were also available on all satellites except MIDAS-4 and PAGEOS. The optical data was catalogued at GSFC and spans of data containing both concentrated laser and the available optical data were selected for analysis. Thirteen orbital arcs (five GEOS-I and eight GEOS-II) from two to four days in length were chosen. The specific time periods of these arcs are presented in Table 2. Arcs of this length have been found to be optimum for the estimation of tracking station coordinates since they are long enough to provide adequate dynamical strength but short enough so that gravity model error does not grow significantly.

The orbital and station coordinate recovery solutions were derived through the use of the GEODYN program (Martin 1972) on the GSFC IBM 360/95 computer. GEODYN is a multiple arc, multiple satellite orbit and geodetic parameter estimation system based upon Cowell type numerical integration techniques. Model parameters included luni-solar gravitational perturbations, solar radiation pressure, the Jacchia Model Atmosphere (1965, 1971) for drag computation, BIH polar motion and UT1 data, and the GEM-1 gravity model (Lerch, et al. 1972).

Processing of this data to date has been primarily concerned with computation of orbital residuals for the Astrosoviet and Eastern European data and a preliminary adjustment of the coordinates for these sites since data from these stations have not previously been available at GSFC. In this respect data from six stations have been analyzed. These stations were:

ASTROSOVIET	EAST EUROPEAN
Oulan Bator, Mongolia	Ondrejov, Czechoslovakia
Uzhgorod, USSR	Potsdam, GDR
Riga, USSR	
Helwan, Egypt	

Figure 1 shows the locations of these stations.

These data were preprocessed with corrections applied in accordance with the information provided in ISAGEX Report No. 16 "Data Handling Booklet" (Brachet 1973).

In the case of the Astrosoviet data we applied corrections for annual and diurnal aberration and parallactic refraction; precession and nutation was applied to convert from the reference system with a mean equator and equinox of 1950.0 to a true of date system. The passive observation time tags were converted from USSR UT1 time to U.S. Naval Observatory (USNO) UTC time.

Corrections for annual and diurnal aberration were applied to the data from Potsdam (1181) and Ondrejov (1147), and parallactic refraction was applied to the Ondrejov data. The passive observation times for these data were converted from the BIH UTC system to the USNO UTC system.

In this solution, coordinates for the ISAGEX lasers and the other cameras were held fixed at the values derived earlier by (Marsh, et al. op. cit.).

3.0 EVALUATION OF THE RESULTS

Table 3 presents a summary of the Astrosoviet and East European camera data used in this solution, the percent of usable data, and the R.M.S. values of the residuals after the adjustment of the station coordinates. The rejection rates ranged from 60% for Potsdam to 6% for Uzhgorod and the R.M.S. values ranged from 3 to 8 arc seconds (topocentric). Figures 2.1 through 7 present plots of typical residual patterns seen in these GEOS-I and GEOS-II arcs. The true data accuracy is probably better than these values indicate since the residuals still reflect the effects of station coordinate error and orbit error.

Figures 2.1 through 4.2 present residuals when several stations observed the GEOS satellites simultaneously. Generally, the residual agreement is good; however, some systematic patterns are noted. For example, in Figure 2.2 it is noted that the Ondrejov declination residuals show a systematic negative trend. Patterns of this nature may be due to a misunderstanding on our part of the preprocessing corrections to be applied to the data, orbit error, station coordinate error, or a bias in the data. Figures 5, 6 and 7 present residuals for passes when the satellite was observed only by an Astrosoviet station. It is noted that the internal precision of the data is probably on the order of two arc seconds or better.

Table 4 presents the old and new coordinate values. The old values were obtained from ISAGEX Report No. 7 (Brachet, 1970). The coordinates for Riga and Uzhgorod presented in this table were computed earlier based upon several hundred NGSP observations (Marsh et al. op. cit.). The uncertainty quoted for these values is three meters in a coordinate. The number of ISAGEX observations available for the present solution was considerably less than that available from the NGSP. Therefore, the present solution served mainly as a check on our ability to process the data submitted during ISAGEX from these two stations and also an evaluation of the accuracy of the orbits used in this analysis. An adjustment of the coordinates for these two stations was nevertheless attempted using only the ISAGEX data. Differences between the values recovered in this solution and those derived earlier were about 20 meters, confirming an accuracy estimate of the present solution.

Differences between the previously available values and the new values range from a few tens of meters to several hundred meters with the largest difference being associated with the height at Oulan Bator (1400 meters). This is most likely due to a typographical error in the old values. The uncertainty in the new values is assessed as being on the order of 20 meters in each coordinate.

4.0 SUMMARY

These analyses represent initial computations at GSFC using camera observations recorded during ISAGEX from several Astrosoviet and East European stations. These analyses have provided a check on our ability to process this new data type and also a preliminary adjustment of the station coordinates.

Recently, CNES indicated that 200 additional optical plates had been submitted to the data bank by the Astrosoviet network. These additional data will be used to extend and refine our analyses.

5.0 REFERENCES

Brachet, G., "International Satellite Geodesy Experiment Plan," ISAGEX Report No. 7, CNES, November 1970.

Brachet, G., "Data Handling Booklet," ISAGEX Report No. 16, CNES, May 1973.

Lerch, F. J., Wagner, C. A., Smith, D. E., Sandson, M. L., Brown, J. E., Richardson, J. A., "Gravitational Field Models for the Earth (GEM 1 and 2)," GSFC Document X-553-72-146, May 1972.

Marsh, J. G., Douglas, B. C., Klosko, S. M., "A Global Station Coordinate Solution Based Upon Camera and Laser Data - GSFC 1973," presented at the First International Symposium on the Use of Artificial Satellites for Geodesy and Geodynamics," Athens, Greece, May 1973, also NASA/GSFC Document X-592-73-171, May 1973.

Martin, T. V., "GEODYN Systems Operation Description," Wolf Research and Development Corporation Final Report on Contract NAS 5-11736-129, February 1972.

Table 1

ISAGEX Precision Reduced Optical Data Received at GSFC as of May 1973

REDUCTION CENTER	GEOS I AND II		ALL NINE SATELLITES	
	PLATES	OBSERVATION PAIRS	PLATES	OBSERVATION PAIRS
SAO (14 STATIONS)	540	1169	957	2050
ASTROSOVIET (6 STATIONS)	38	270	99	2425
GRGS (5 STATIONS)	140	787	243	1279
U.K. (2 STATIONS)	17	110	17	110
DELFT	27	139	27	139
ONDREJOV	34	299	54	406
ZIMMERWALD	26	142	26	142
SOFIA	0	0	2	279
BAJA	0	0	7	149
BUCHAREST	0	0	6	327
POTSDAM	12	87	18	158
TOTAL	834	3003	1456	7464

592-2147
SEPT 73

Table 2

Orbital Arcs Used in Dynamical Solution

SATELLITE	TIME PERIOD (1971)
GEOS-1	FEB. 23 TO 26 FEB. 26 TO 29 MARCH 2 TO 7 MARCH 10 TO 14 MARCH 24 TO 29
GEOS-II	APRIL 1 TO 5 APRIL 6 TO 10 APRIL 13 TO 16 APRIL 21 TO 25 APRIL 29 TO MAY 3 MAY 9 TO 13 AUGUST 9 TO 13 AUGUST 20 TO 24

592-2145
SEPT 73

Table 3

Summary of ISAGEX Precision Reduced Astrosoviet and East European Optical Data Used for Station Coordinate Adjustment

STATION	OBSERVATIONS* AVAILABLE	OBSERVATIONS USED	PERCENT USED	RMS OF FIT (ARC SECONDS)
ASTROSOVIET				
OULAN BATOR, MONGOLIA	60	41	70	3.8
UZHGOROD, USSR	36	34	94	4.8
RIGA, USSR	100	57	57	4.3
HELWAN, EGYPT	64	43	56	3.1
EAST EUROPEAN				
ONDREJOV, CZECHOSLOVAKIA	168	99	59	6.1
POTSDAM, GDR	94	38	40	8.5

*RIGHT ASCENSION PLUS DECLINATION MEASUREMENTS.

592-2144
SEPT 73

Table 4

Astrosoviet and East European Station Coordinate Values

STATION		LATITUDE	LONGITUDE(E)	HEIGHT
OULAN BATOR, MONGOLIA	NEW VALUE	47°51′57.4″	107°03′11.3″	1575 m.
	OLD VALUE*	47°51′56″	107°03′00″	175
	DIFFERENCE	1.4″ OR 40 m.	11.3″ OR 340m.	1400
HELWAN, EGYPT	NEW VALUE	29°51′44.6″	31°20′38.2″	150 m.
	OLD VALUE*	29°51′31.1″	31°20′28.05″	120
	DIFFERENCE	13.5″OR400 m.	10.1″ OR 300 m.	30
ONDREJOV, CZECHOSLOVAKIA	NEW VALUE	49°55′16.9″	14°47′53.2″	560 m.
	OLD VALUE*	49°55′19.4″	14°48′3.9″	537
	DIFFERENCE	2.5″ OR 75m	10.7″ OR 320m	23
POTSDAM, GDR	NEW VALUE	52°22′49.7″	13°03′54.9″	211 m.
	OLD VALUE*	52°22′51.4″	13°03′58.8″	109
	DIFFERENCE	1.7″ OR 50 m.	3.9″ OR 120 m.	102
RIGA, USSR	NEW VALUE+	56°56′55.44″	24°3′32.47″	11 m.
	OLD VALUE*	56°56′54.98″	24°3′37.81″	2
	DIFFERENCE	0.5″ OR 15 m.	5.3″ OR 160 m.	9
UZHGOROD, USSR	NEW VALUE +	48°38′1.83″	22°17′55.47″	216 m.
	OLD VALUE*	48°38′4.56″	22°17′57.88″	189
	DIFFERENCE	2.7″ OR 80 m.	2.4″ OR 70 m.	27

COORDINATES ARE REFERRED TO AN ELLIPSOID WITH; a_e = 6378155m., 1/f = 298.25

+FROM MARSH, DOUGLAS, KLOSKO, 1973, "A GLOBAL STATION COORDINATE SOLUTION BASED UPON CAMERA AND LASER DATA - GSFC 1973" GSFC DOCUMENT X-592-73-171.

*FROM BRACKET, 1970, "INTERNATIONAL SATELLITE GEODESY EXPERIMENT PLAN," ISRGEX REPORT NO. 7, CNES

SEPT 73

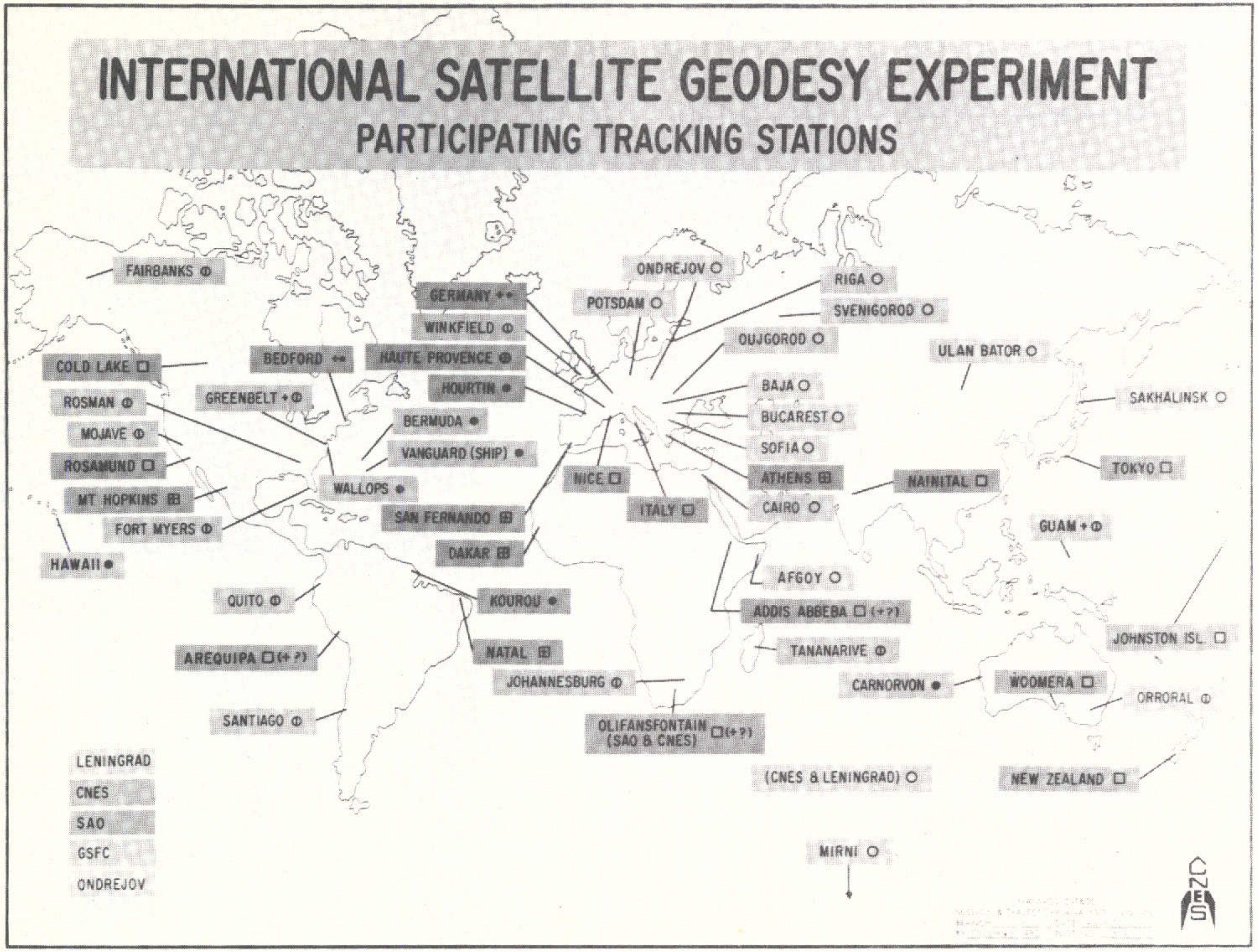


Figure 1. International Satellite Geodesy Experiment (Participating Tracking Stations)

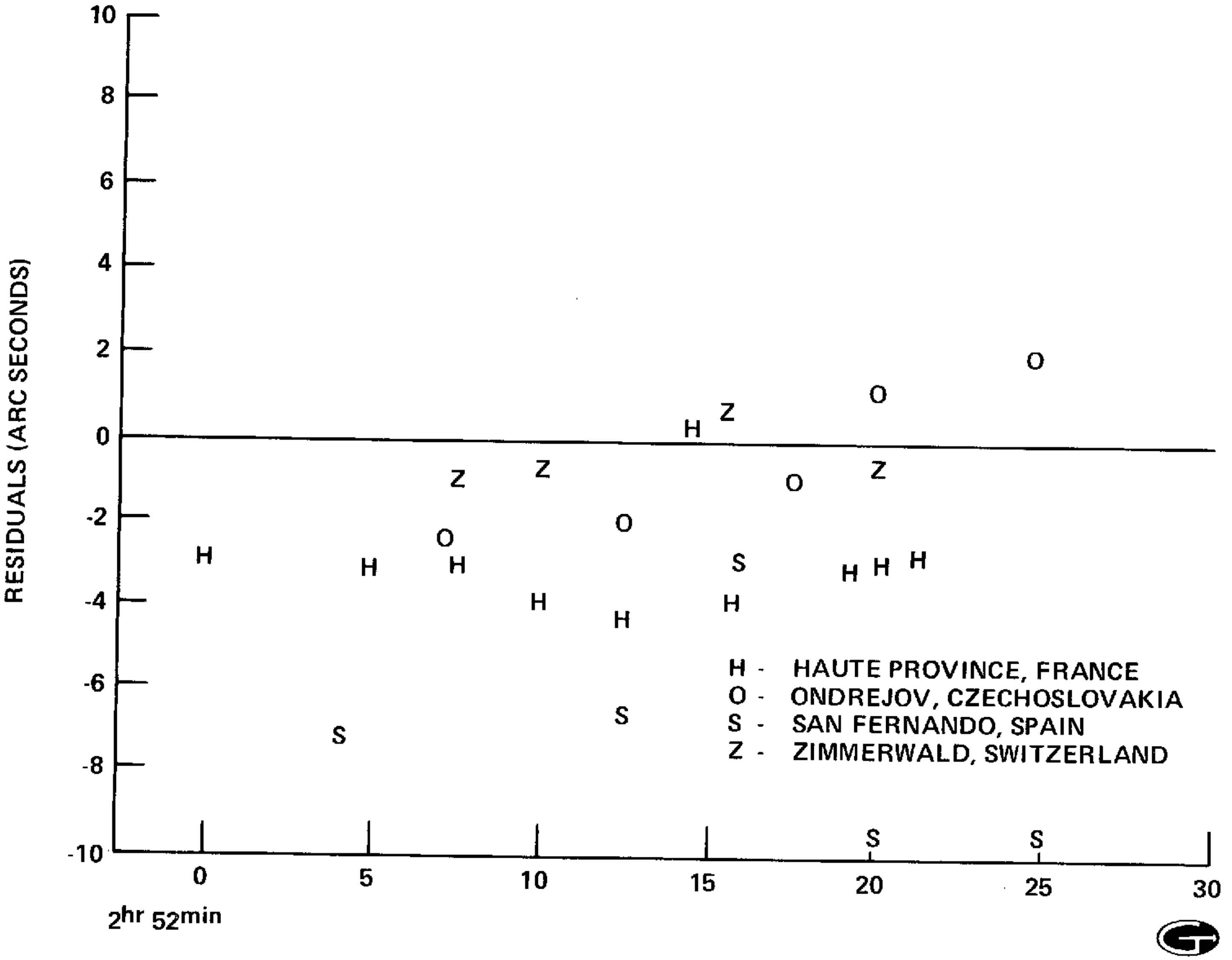


Figure 2.1. GEOS-II Right Ascension Residuals April 15, 1971

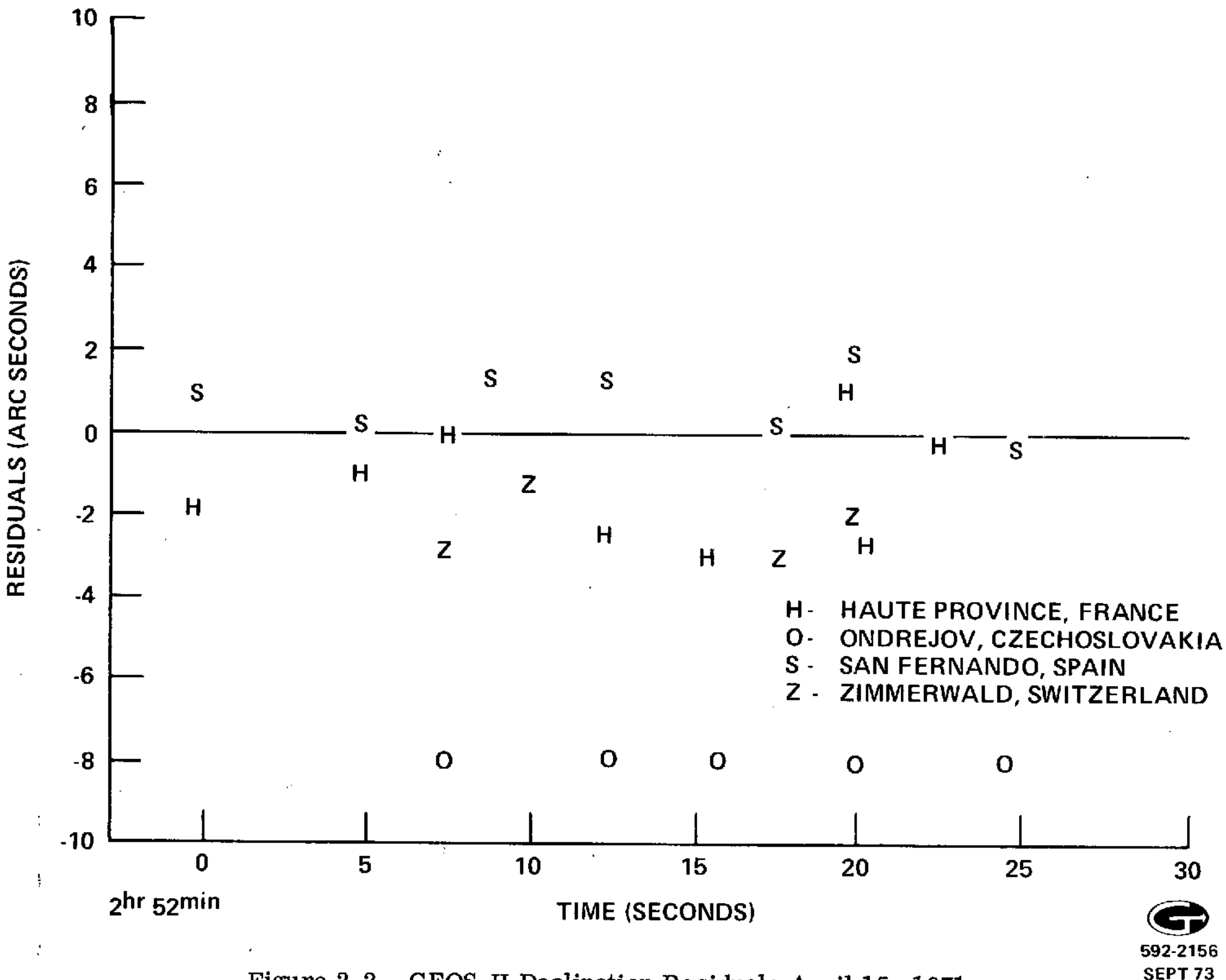


Figure 2.2. GEOS-II Declination Residuals April 15, 1971

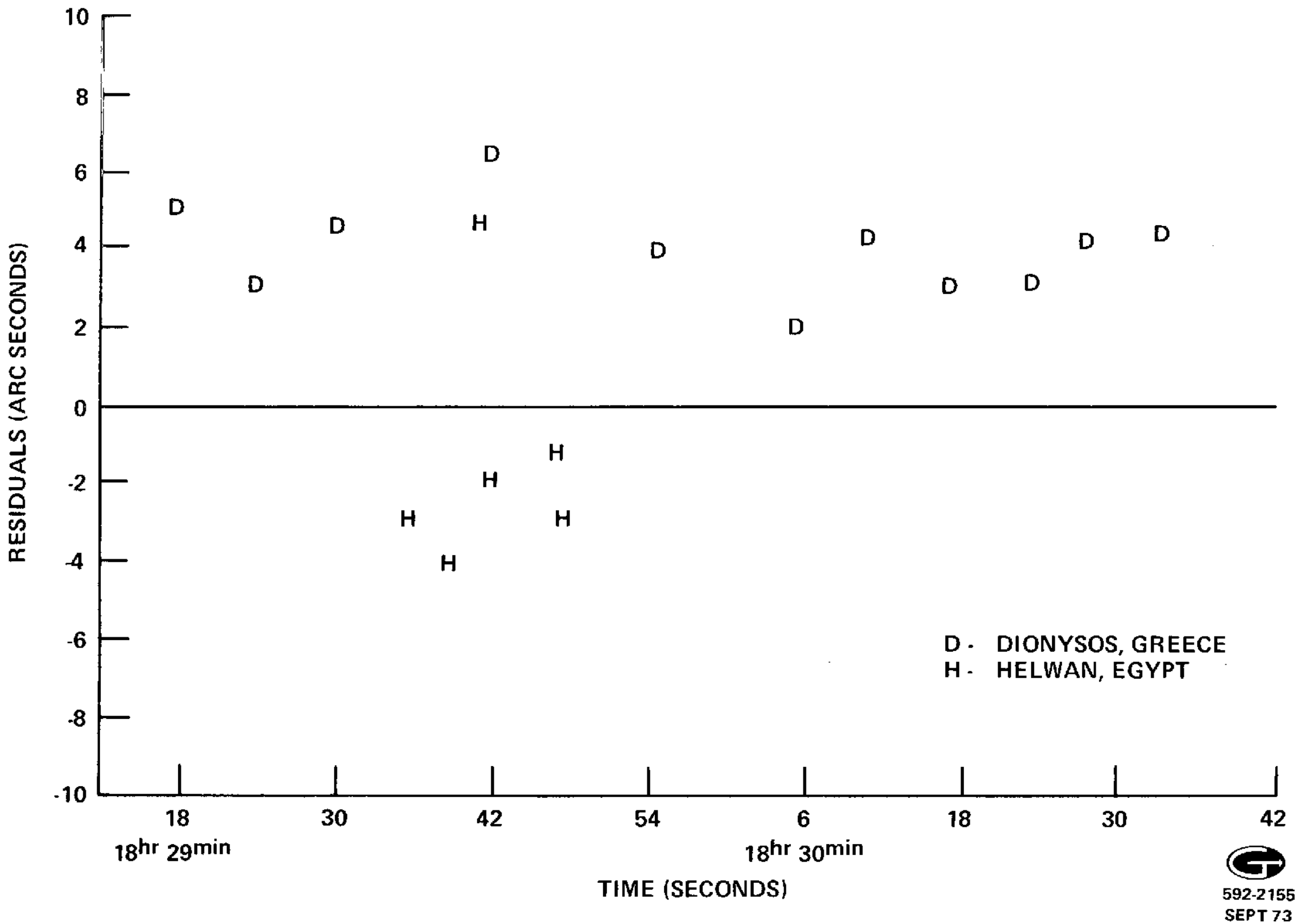


Figure 3.1. GEOS-II Right Ascension Residuals April 20, 1971

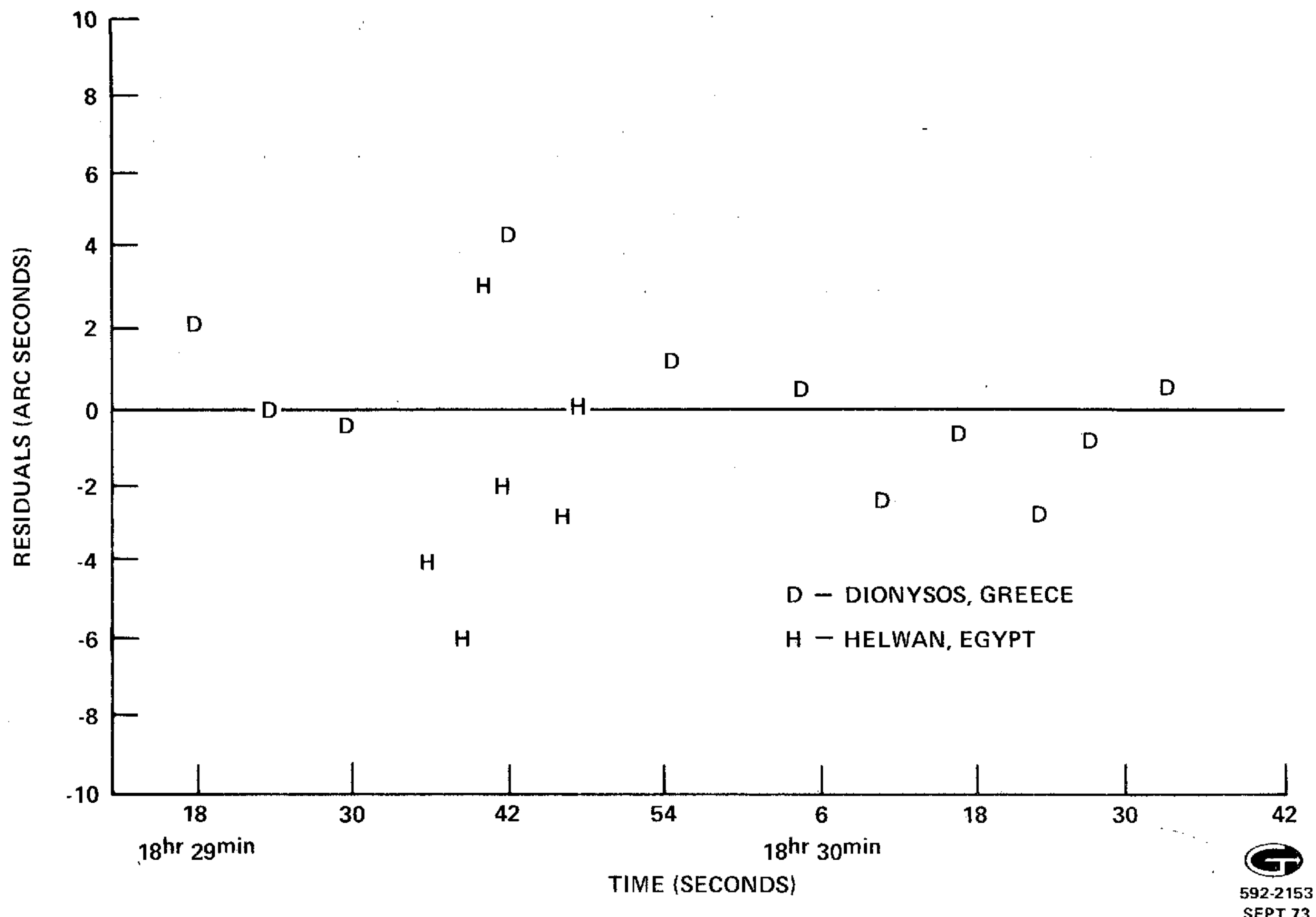


Figure 3.2. GEOS-II Declination Residuals April 20, 1971

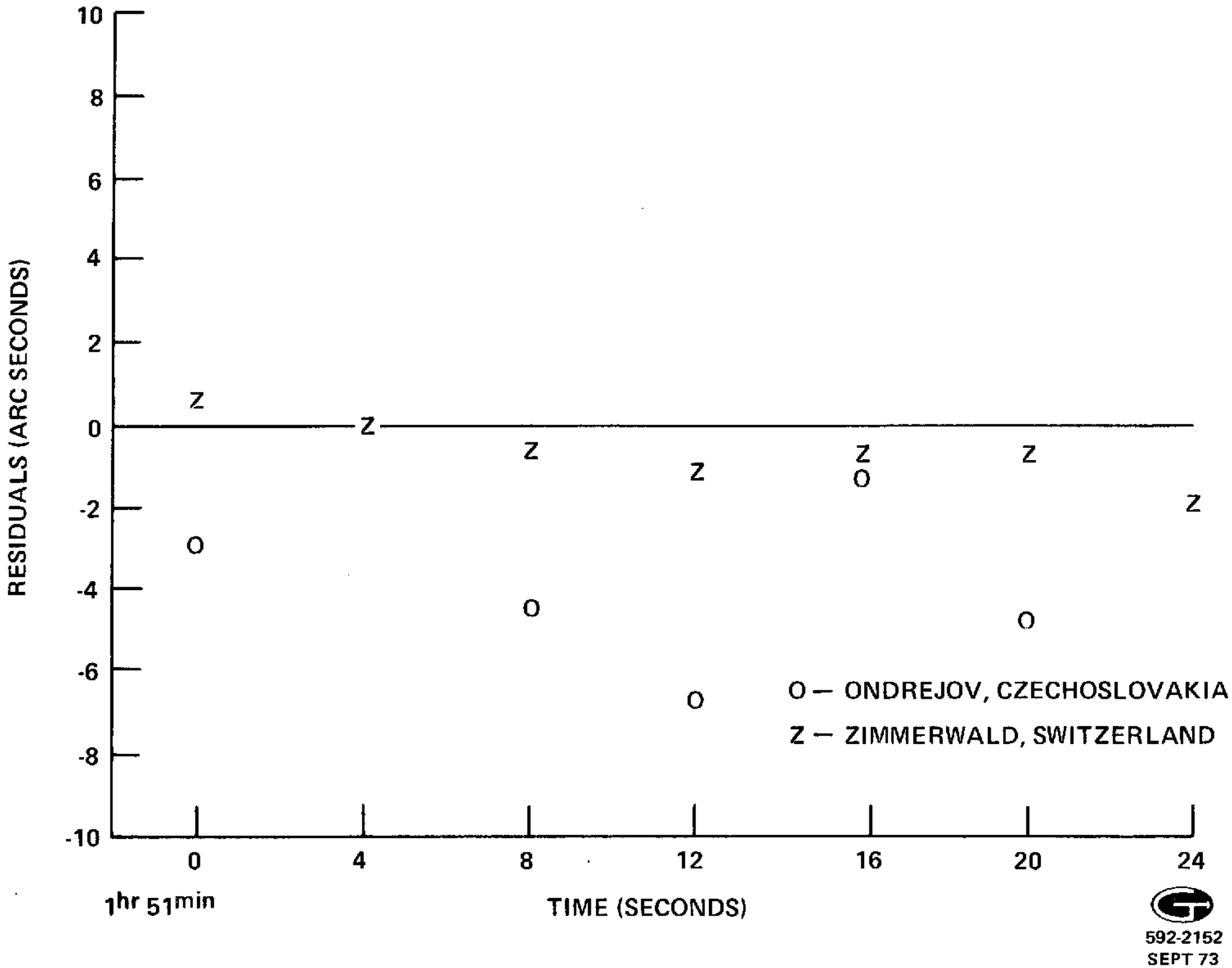


Figure 4.1. GEOS-II Right Ascension Residuals April 29, 1971 [Flashing Lamps]

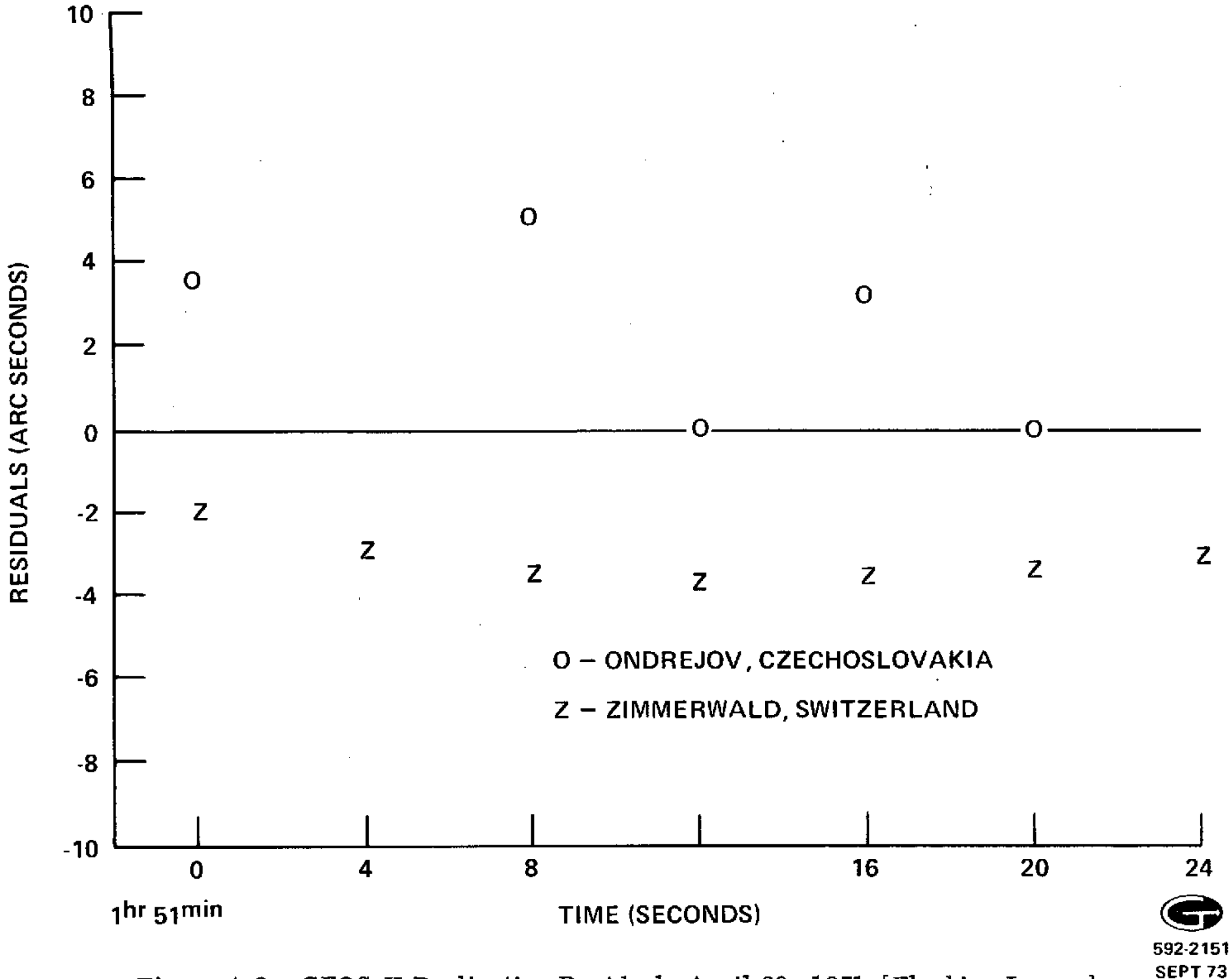
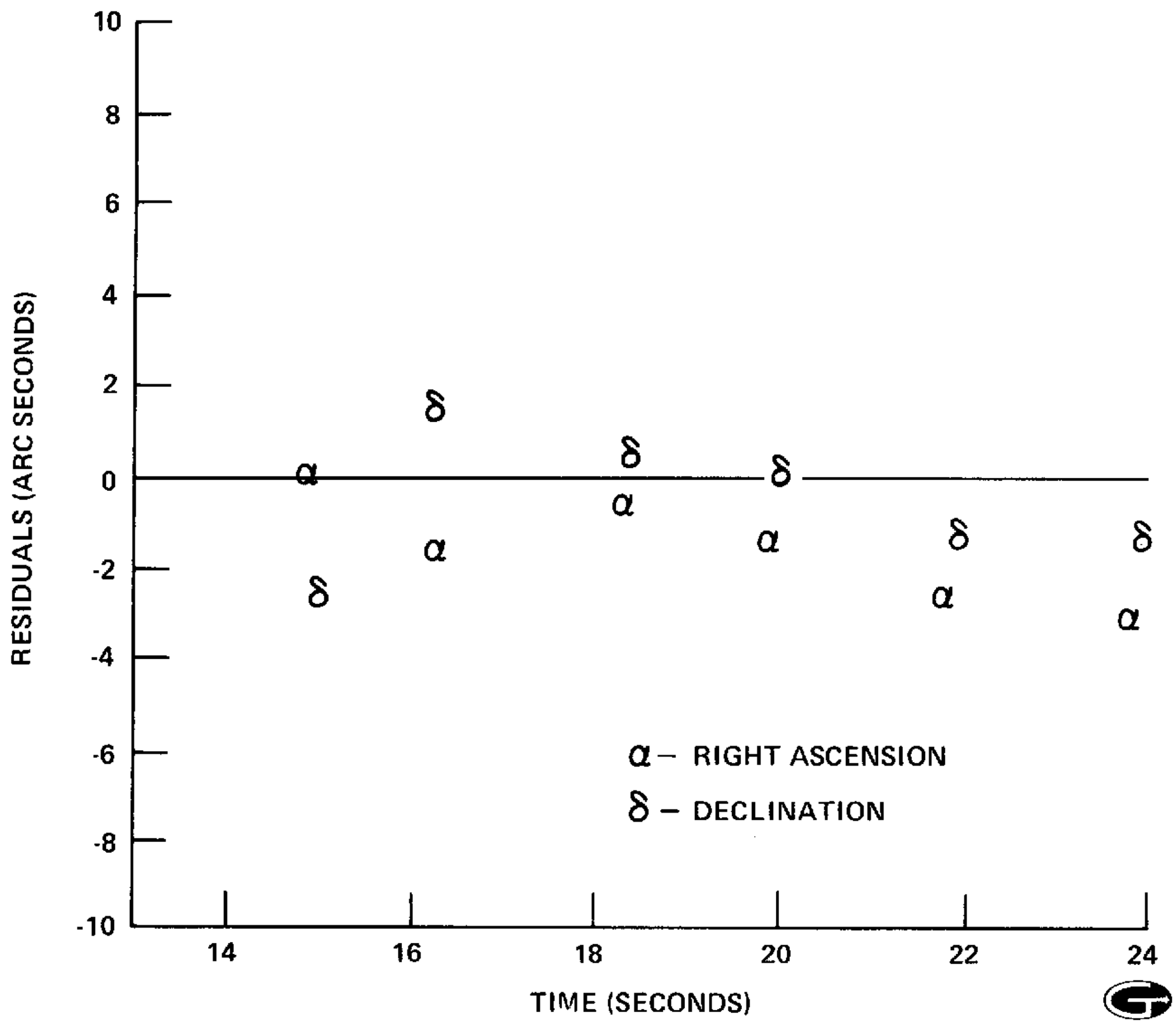


Figure 4.2. GEOS-II Declination Residuals April 29, 1971 [Flashing Lamps]



592-2150
SEPT 73

Figure 5. GEOS-II Residuals, Helwan, Egypt August 9, 1971

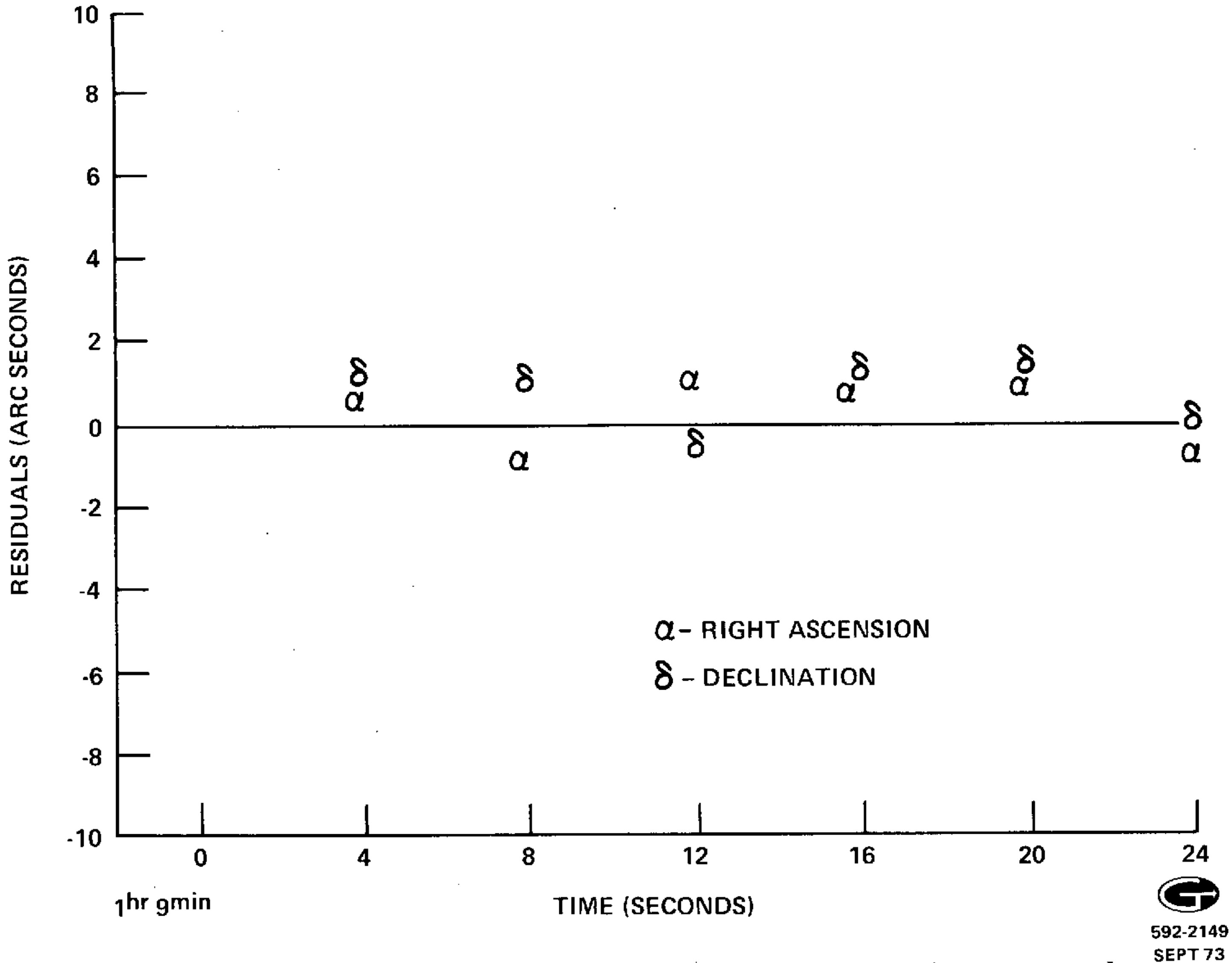


Figure 6. GEOS-II Residuals, Uzhgorod, USSR April 21, 1971 [Flashing Lamps]

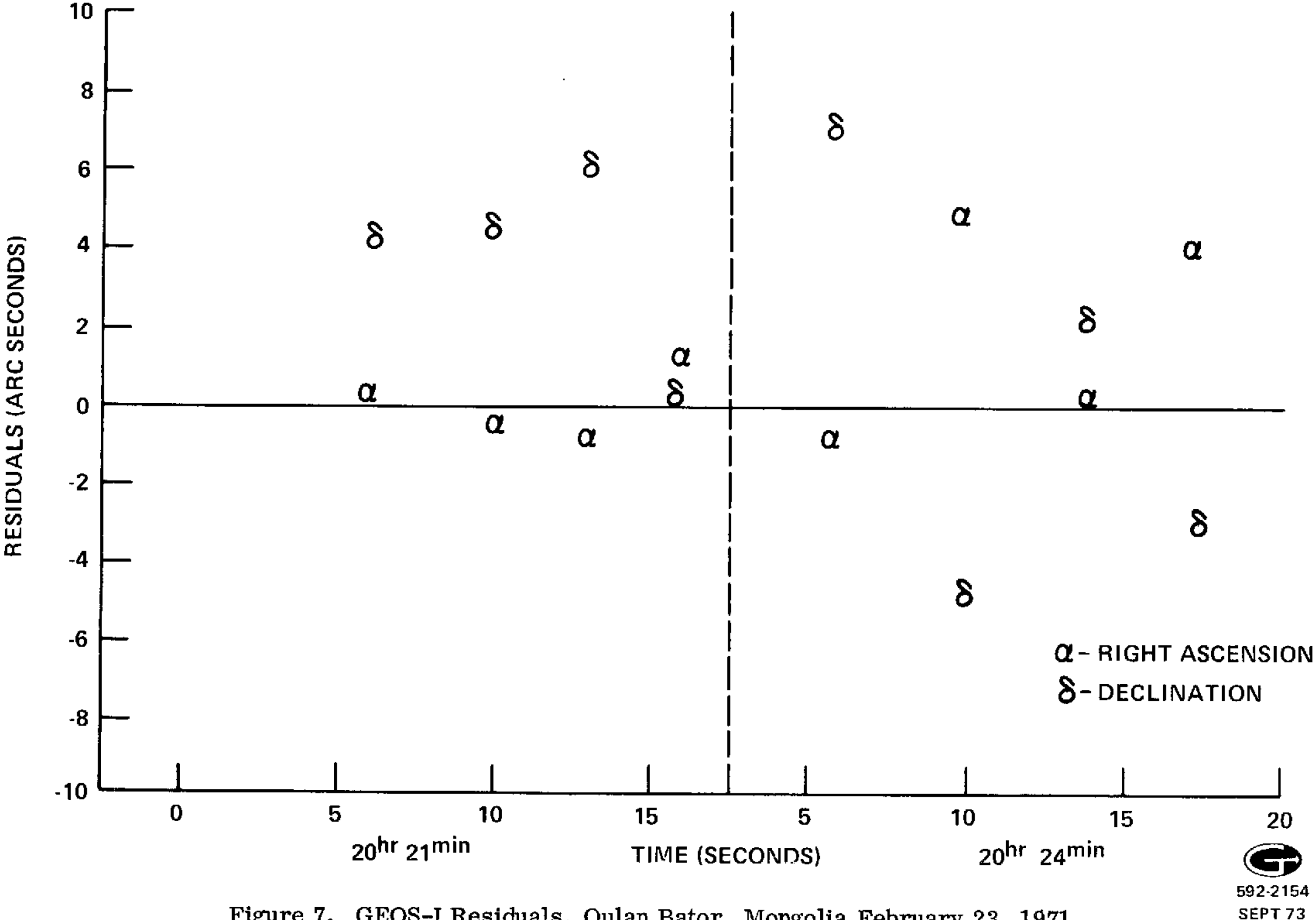


Figure 7. GEOS-I Residuals, Oulan Bator, Mongolia February 23, 1971